Page (1) ID = 4795
Abubakar

QNo1:-

Stirrups:-

A stirrups is a closed loops of reinforcement bar that is used to hold the main reinforcement bar together in an RCC structure.

Types of stirrups:-

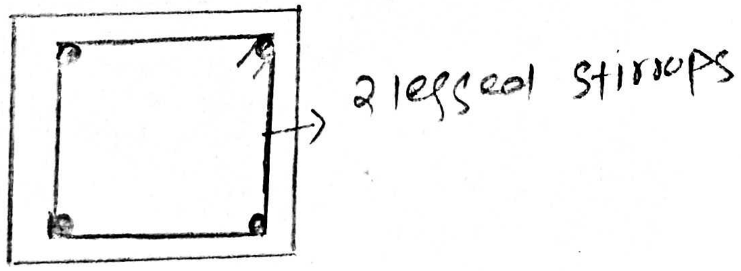
The following types of stirrups are widely used in construction.

1) single legged stirrups:-

used ~~only~~ when bending only two rods.

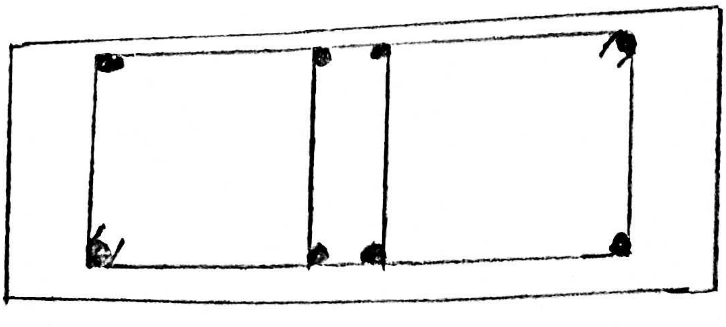
2) Two legged stirrup:-

It is most commonly and widely used stirrups. minimum 4 bars are required for providing this stirrops.

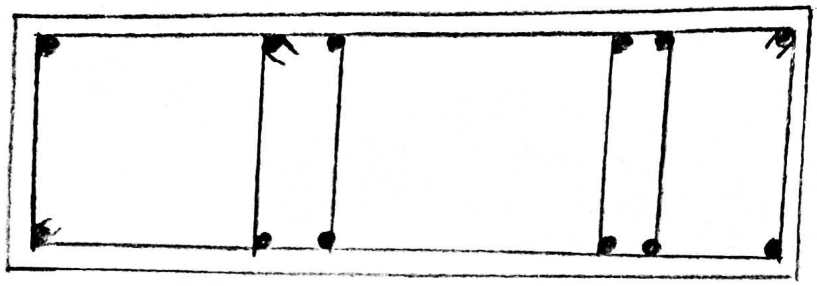


3) Four legged stirrups:-

The stirrups are used in case of web reinforcement.



4) Six legged stirrups:-



ACI codes for shear design of a beam:-

⇒ According to ACI-318, following are the formula used for the shear design of a beam.

1) Critical section:-

⇒ Critical section occurs at 45° and is at distance (d) from the face of support which is equal to the effective depth.

2) Shear strength capacity of concrete is:-

⇒ $Vc = 2 \times \sqrt{fc'} \times bw \times d$

3) Minimum web reinforcement:-

⇒ If $Vu \leq \phi Vc$, then theoritically no web reinforcement is required. However ACI code require provision of at least a minimum area of web reinforcement equal to

$\phi = 0.75 \rightarrow$ for shear design.

∴ VU = Total factored shear applied at a given section

4) ⇒ For minimum reinforcement area:-

$Av_{min} = 0.75 \times \sqrt{fc'} \times bw \times d / fy$ or $\dfrac{50 \times bw \times S}{fy}$ → Higher value is selected.

by interchange the above formula we can obtain the formula of maximum facing.

$S_{max} = \dfrac{Av \times fy}{0.75 \times \sqrt{fc'} \times bw}$ or $\dfrac{Av \times fy}{50 \times bw}$ → lesser value is selected.

5) **No web-reinforcement is required if**

$\Rightarrow V_u < \frac{1}{2}\phi V_c$

Between critical section "V_u" and "ϕV_c" spacing between web reinforcement can be find by

$$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c}$$

6) $\Rightarrow$

If $V_s \leq 4 \times \sqrt{f'_c} \times b_w \times d$, then max spacing for stirrups will be the smallest of the following

1 - 24"

2 - $d/2$

3 - $S_{max} = \dfrac{A_v \times f_y}{0.75 \times \sqrt{f'_c} \times b_w}$

4 - $S_{max} = \dfrac{A_v \times f_y}{50 \times b_w}$

$\Rightarrow$ If $V_s > 4 \times \sqrt{f'_c} \times b_w \times d$

max spacing will be halved

$\Rightarrow$ If $V_s > 8 \times \sqrt{f'_c} \times b_w \times d$

Then either increase cross-sectional dimension or increase f'_c.

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QNO # 02

Numerical:-

Given:-

Breadth of web of beam (bw) = 14"

Effective depth (d) = 22"

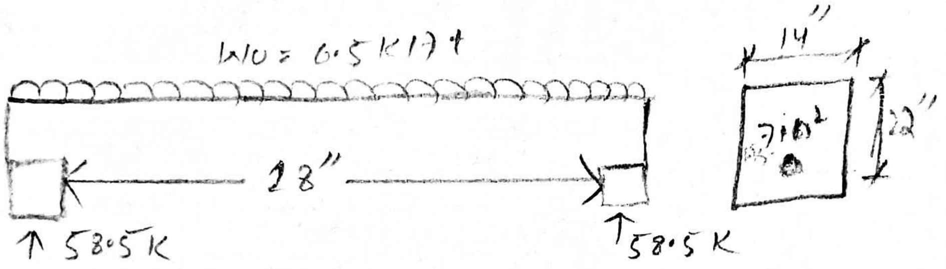
Given load = 6.5 K/ft

Steel area = 7 in²

$f_c' = 4$ Ksi

$f_y = 60$ Ksi

Sol:- As

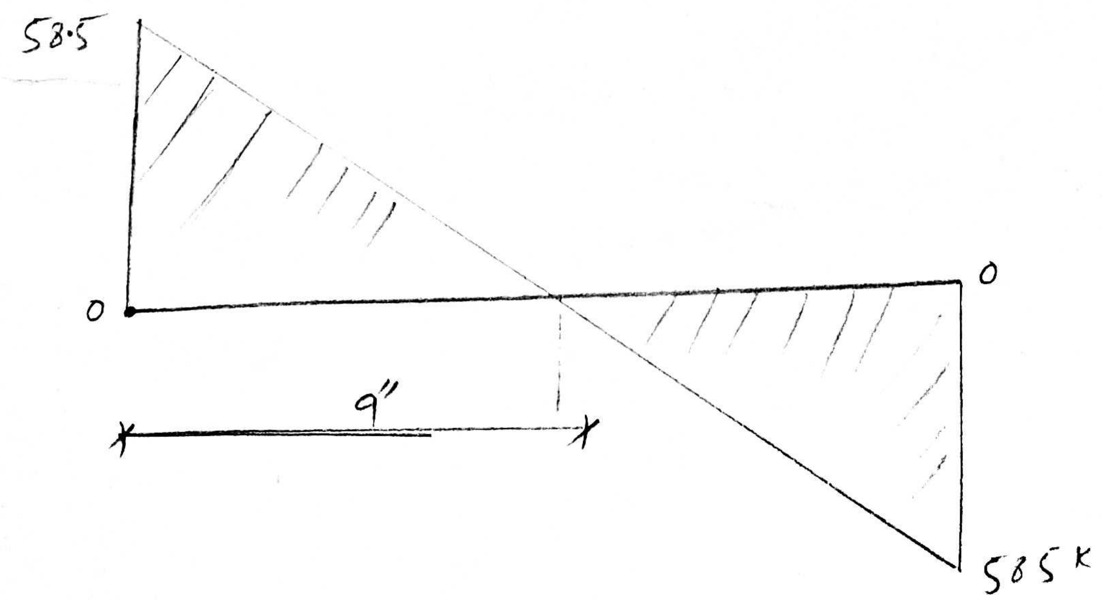


Step # 1:- Reaction on supports:-

Finding the reactions due to applied load

Total load = $6.5 \times 18/2$ = 58.5 Kips

Step #2:- (Shear force diagram)

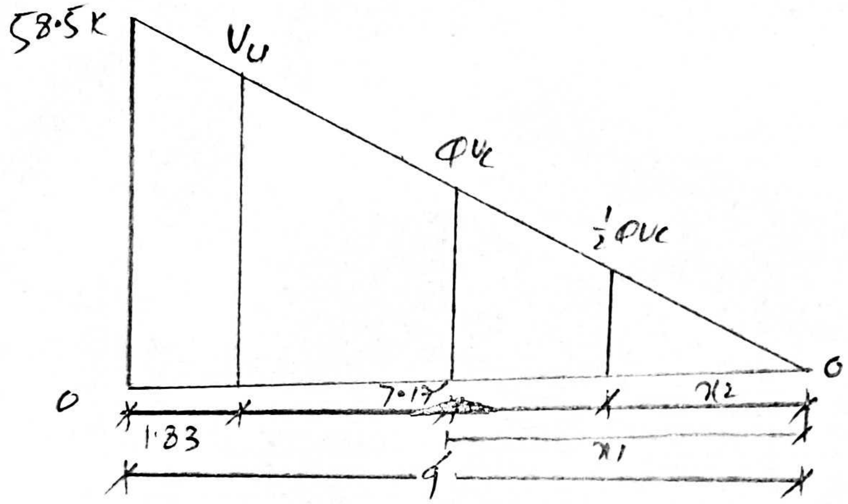


step #3:-

⇒ Finding the value of critical shear "Vu" and its location. As

⇒ We know that critical shear is located at distance 'd' from the face of support (d) = 22" = 1.83"

⇒ We will find the value of critical shear at distance 'd' by use of similar triangles.



From similar triangle

$58.5/9 = Vu/8.17$

$$Vu = \frac{58.5 \times 8.17}{9}$$

$$\boxed{Vu = 46.61 \text{ kips}}$$

step #4:-

finding the value of 'φVc' and "½ φVc"

by formula

$$\phi Vc = \phi \times 2 \times \sqrt{f'c} \times bw \times d$$
$$= 0.75 \times 2 \times \sqrt{4000} \times 14 \times 22$$
$$= 29219 \text{ lbs} = 29.21 \text{ kips}$$

⇒ location of φVc by similar triangles.

$$\frac{58.5}{9} = \frac{\phi Vc}{x1} = \frac{58.5}{9} = \frac{29.21}{x1}$$

$$= x1 = 4.49'$$

⇒ similarly,

$\frac{1}{2}\phi V_c = \frac{\phi V_c}{2} = 29.21/2 = 14.60$ kips

⇒ location of $\frac{1}{2}\phi V_c$ will be,

$\frac{58.5}{9} = \frac{\frac{1}{2}\phi V_c}{x_2} \Rightarrow \frac{58.5}{9} = \frac{14.60}{x_2}$

$\Rightarrow \boxed{x_2 = 2.24'}$

step#5:-

finding the value of ϕV_s formula $V_u = \phi V_s + \phi V_c$

$\phi V_s = V_u - \phi V_c$

$= 46.61 - 29.21$

$\boxed{\phi V_s = 17.4 \text{ kips}}$

step#6:- check on section adequacy

by formula

$\phi \times 8 \times \sqrt{f_c'} \times b_w \times d$

$= 0.75 \times 8 \times \sqrt{4000} \times 14 \times 22$

$= 116877$ lbs $= 116.87$ kips.

As $\phi \times 8 \times \sqrt{f_c'} \times b_w \times d > \phi V_s$

so section is adequate.

step # 7:- check on maximum spacing for stirrups.

by formula

$\phi \times 4 \times \sqrt{f_c'} \times b_w \times d$

$= 0.75 \times 4 \times \sqrt{4000} \times 14 \times 22 = 58438$ lbs

58.43 kips

As $\phi \times 4 \times \sqrt{f_c'} \times b_w \times d > \phi V_s$

so maximum will be selected ~~by~~ from the following four condition.

∴) we use #3 stirrups

$dia = \frac{3}{8} = 0.375$

$Area = \frac{\pi}{4}(0.375)^2 = 0.11 in^2$

For 2 legged stirrups

$Area \times 2$

$0.11 \times 2 = 0.22 in^2$

1) ⇒ $S_{max} = 24''$

2) $d/2 = \frac{22}{2} = 11''$

3) ⇒ $S_{max} = \frac{A_v \times f_y}{0.75 \times \sqrt{f'c} \times b_w}$

$S_{max} = \frac{0.22 \times 6000}{0.75 \times \sqrt{4000} \times 14} = 19.87''$

4) $S_{max} = \frac{A_v \times f_y}{50 \times b_w} = \frac{0.22 \times 6000}{50 \times 14} = 18.85''$

from above 4 condition, least value of spacing for #3, 2 legged stirrups will be selected as $S_{max} = 11''$

Step # 8:-

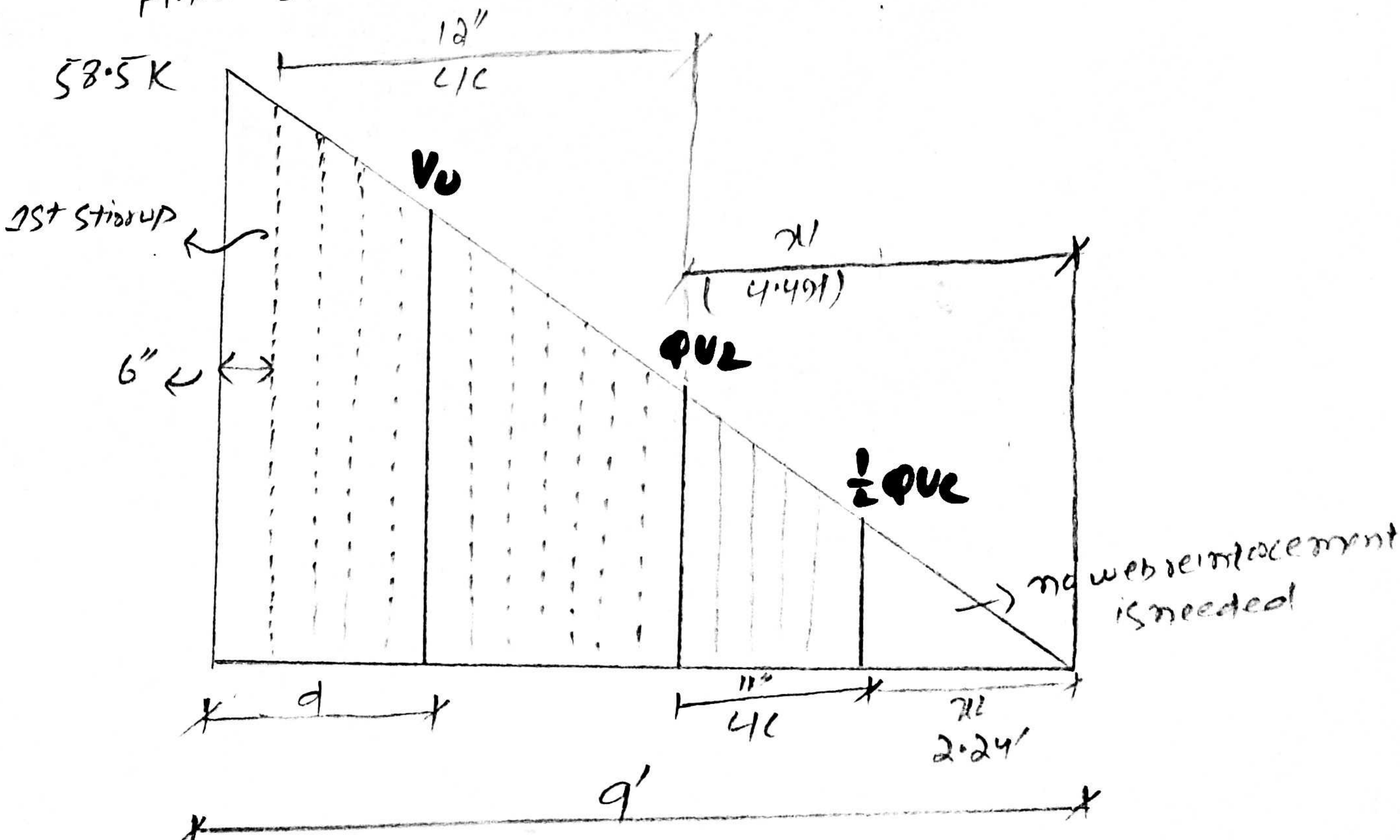
Stirrups spacing at critical section

$S = \frac{\phi \times A_v \times f_y \times d}{V_u - \phi V_c} = \frac{0.75 \times 0.22 \times 60 \times 22}{46.61 - 29.21} = S = 12.5'' \cong 12$

so $S = 12''$ c/c.

Step # 9:-

Final sketch will be.



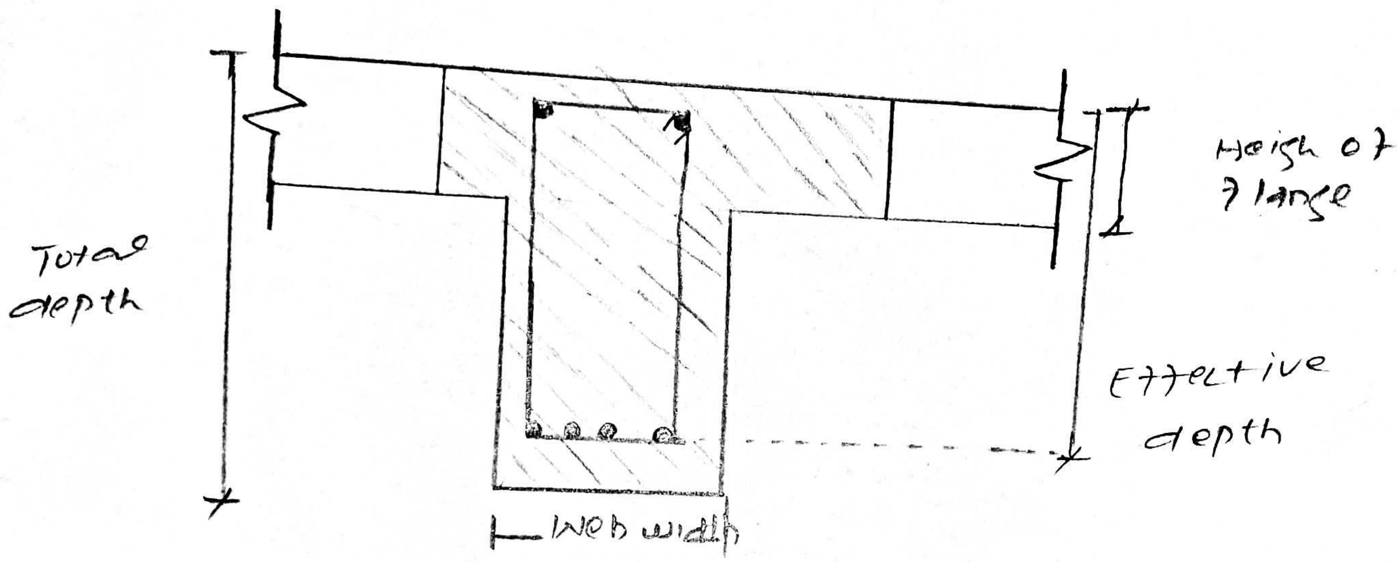
QNO3:-

Define T and L beam and also explain flexural analysis of T-beam

ANS:-

T-beam:-

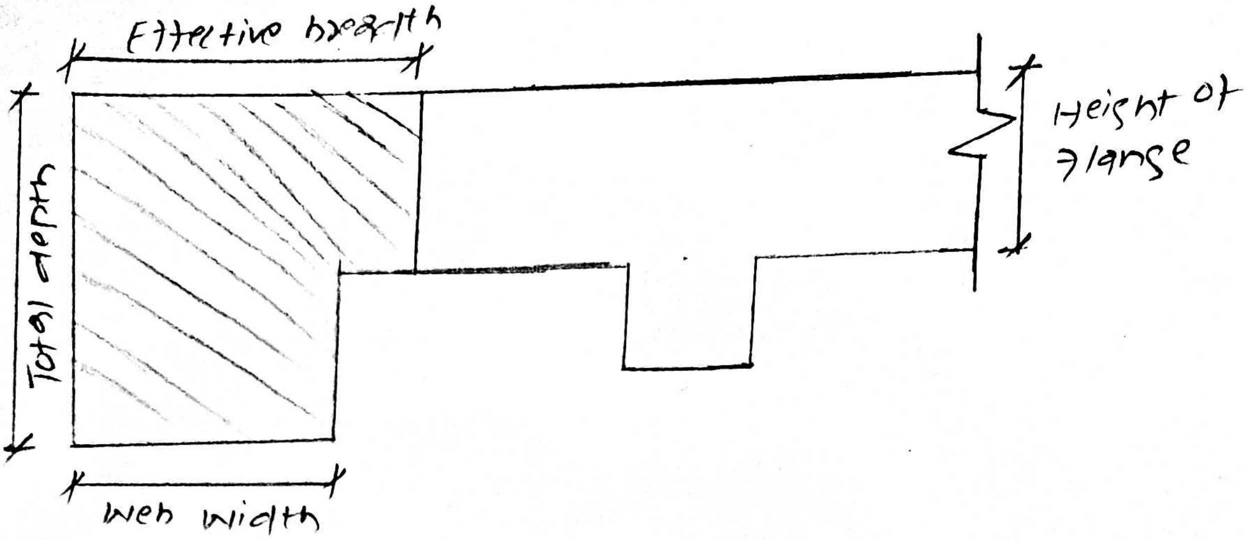
In most of the reinforced concrete structures, concrete slabs are cast monolithically with the slab so, in this case the beam that act as an intermediate beam are called T- beam.



- Because of their T-shape, these beams are called T- beam.
- It is provided at the center of of the slab to resists the loads.
- The upper most area of the beam attached to the slab is called flange.
- The bottom rectangular portion of the beam is called web of the beam.

L-beam:-

- L-shaped structure that is in contact with slab and present at the corner of the floor is called L- beam.



⇒ L-beams are also called Edge beams.
⇒ It is always provided at the corner of the slab.
⇒ L-beam are typical floor beams because of their reduced overall structural depth, the beam are in prestressed or reinforced concrete.

Flexural analysis of T-beam:-

Flexural analysis of T-beam consists of the following steps:-

1) For finding the ultimate factored moment, we use the following formula.

$$Mu = \frac{wu \times L^2}{8}$$

2) ⇒ Effective width (be) for T-beam is calculated as

1) $16(hf) + bw$
2) c/c distance
3) span/4
4) $\frac{CTS}{2} + bw$

∴ hf = height of flange.
CTS = clear transverse span

We have to select the least value from above formulas.
If c/c distance is given, then there is no need of $\frac{CTS}{2} + bw$.

3) Checking whether rectangular or T- beam analysis is required:-

i) If $a > hf$ → special analysis is required

ii) if $a < hf$ → Rectangular beam analysis is required

where

a = depth of compression block

hf = height of flange.

4) ⇒ for finding area of steel, we have to use

$$A_{st} = \frac{M_u}{\phi \times f_y' \times (d - a/2)}$$

where $a = \dfrac{A_{st} \times f_y}{0.85 \times f_c' \times b_w}$

∴ ϕ = strength reduction factor

d = effective depth

a = compression block depth

b_w = web width of beam

5 ⇒ for checking the range of reinforcement ratio

$$\rho_{max} = 0.85 \times \beta \times \frac{f_c'}{f_y} \times \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}\right)$$

$$\rho_{min} = 200/f_y$$

$$\rho = A_{st}/b \times d$$

6) ⇒ formula for finding No of bars required is.

$$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}}$$

7 ⇒ Design moment is given by

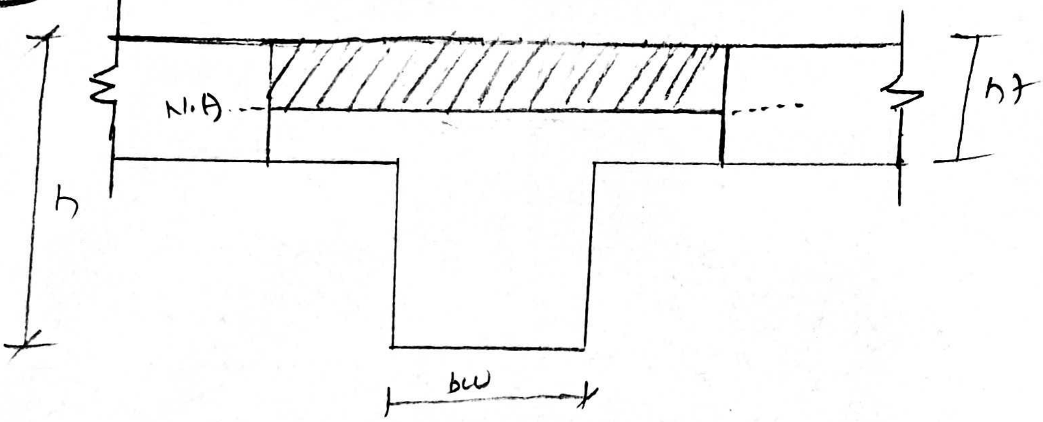
$$M_d = \phi \times f_y \times A_{st} \times (d - a/2) \rightarrow a < hf$$

$$M_d = \phi \times [A_s \times f_y \times (d - \frac{hf}{2}) + (A_s - A_{st}) + f_y \times (d - \frac{a}{2}) \rightarrow a > hf$$

Q#

Difference b/w case I and case II in the design of T-beam.

Case I:-



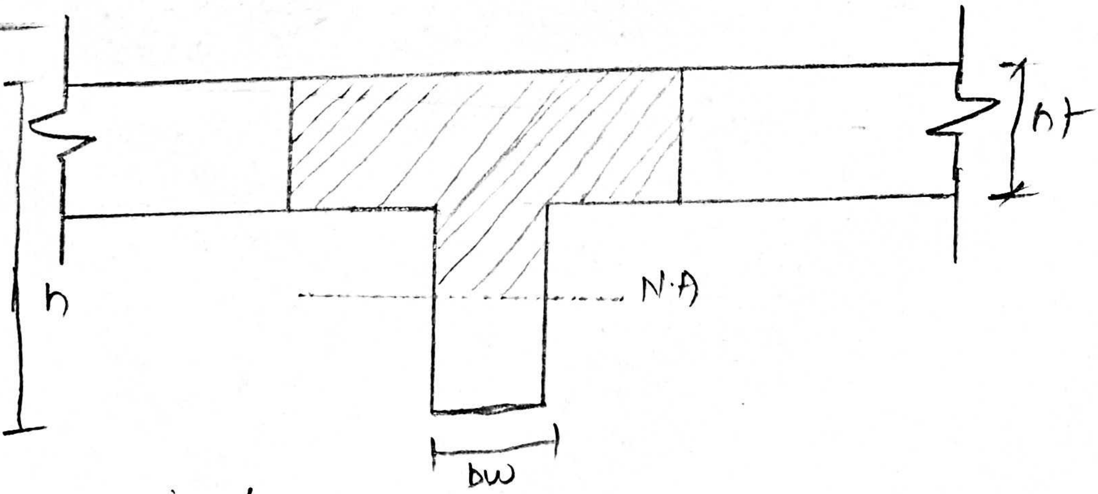
from above figure $a < h_f$.

so in this case, rectangular beam analysis is required.

so, The design moment formula will be

$$M_d = \phi \times f_y \times A_{st} \times (d - a/2)$$

Case II:-



from the figure

$a > h_f$

so in this, special beam analysis is required.

so the required design moment will be,

$$M_d = \phi \times \left[A_s \times f_y \times \left(d - \frac{h_f}{2}\right) + (A_s - A_{st}) + f_y \times d - \frac{a}{2}\right]$$

Q # 5

Numerical :-

Given :-

Height of flange (h_f) = 3.5"

c/c distance = 9'

span of the beam = 16'

web width (b_w) = 10"

Effective depth (d) = 18"

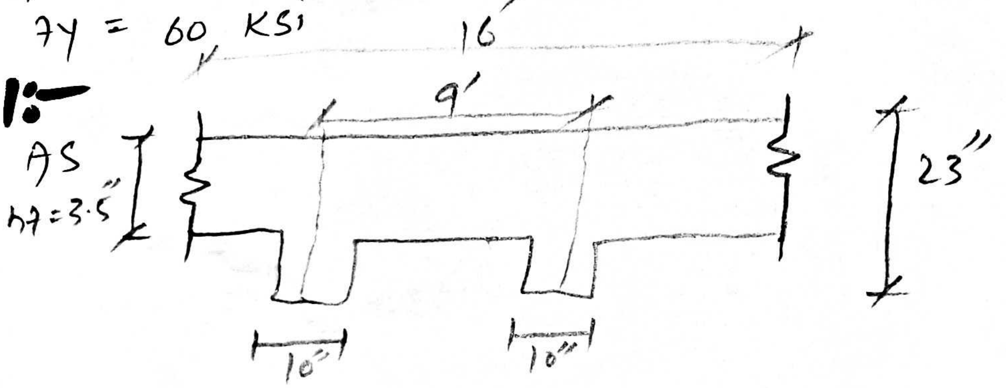
height (h) = 23"

Total factored moment (M_u) = 5800 kiph-inch

f_c' = 3 ksi

f_y = 60 ksi

Sol :-



step # 1 :-

calculate the effective width (b_e) for T- beam

1) $16(h_f) + b_w$ = $16(3.5) + 10$ = 66"
2) c/c distance = 9×12 = 108"
3- span/4 = $\frac{16}{4} \times 12$ = 48"

select the least value

$b_e = 48"$

step # 2

check whether rectangular or T- beam analysis is required.

P.T.O.

Trial #1:-

let $a = hf = 3.5''$

$$A_{st} = \frac{M_u}{\phi \times f_y \times (d - \frac{a}{2})} = \frac{5800}{0.90 \times 60 (18 - \frac{3.5}{2})} = 6.61 in^2$$

Trial #2

$$a = \frac{A_{st} \times f_y}{0.85 \times f_c' \times b_w}$$

$$= \frac{6.61 \times 60}{0.85 \times 3 \times 48} = 3.2''$$

And $\boxed{A_{st} = 6.55 \, in^2}$ $\Rightarrow$ $3.2'' < 3.5''$

so rectangular beam design is required.

Trial #3

$a = 3.21''$

and $A_{st} = \dfrac{5800}{0.90 \times 60 (18 - \frac{3.21}{2})} = 6.55 \, in^2$

so area of steel is $6.55 \, in^2$

step#3

Check ρ_{max} and ρ_{min}

$$\Rightarrow \rho_{max} = 0.85 \times \beta \times \frac{f_c'}{f_y} \left(\frac{\varepsilon_u}{\varepsilon_u + \varepsilon_t} \right)$$

$$= 0.85 + 0.85 \times \frac{3}{60} \left(\frac{0.003}{0.003 + 0.005} \right) = 0.013$$

$$\Rightarrow \rho_{min} = \frac{200}{f_y} = \frac{2000}{60000} = 0.003$$

$$\Rightarrow \rho = \frac{A_{st}}{b \times d} = \frac{6.55}{10 \times 18} = 0.036$$

$\rho_{min} < \rho < \rho_{max}$

$0.003 < 0.036 < 0.013$

As the value of ρ_{max} is less than ρ, so we have to design it as doubly reinforced beam.

First we have to find the area of steel against ρ_{max}.

$\rho_{max} = \frac{Ast}{b \times d} \Rightarrow Ast = \rho_m (b \times d)$

$= 0.013 \times (10 \times 18)$

$\boxed{Ast = 2.34 in^2}$

Step #4

Finding the value of MUL:-

by formula

$MUL = \phi \times Ast \times fy \times (d - a/2)$

first finding the value of 'a'

$a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{2.43 \times 60}{0.85 \times 3 \times 10}$

$a = 5.72''$

$MUL = 0.90 \times 2.43 \times 60 \times (18 - \frac{5.72}{2})$

$\boxed{MUL = 1986.67 \text{ Kip-inch}}$

As $MUL < MU$

$1986.67 < 5800$

So we have to design the beam in such a way that it can resist more bending moment than the applied external moment.

Step #5:-
Finding difference is moments and area of steel.

$Mu_1 = Mu - Mu_2$
$= 5800 - 1986.67$
$\boxed{Mu_1 = 3813.33 \text{ Kip-inch}}$

by formula
$A'st = \frac{Mu}{\phi \times fy \times (d-d')} = \frac{3813.33}{0.90 \times 60 \times (18-2.5)}$

$\boxed{A'st = 4.56 \, in^2}$

Step #6:-
Finding total steel area
$As = Ast + Ast'$
$= 2.43 + 4.56 = 6.99 in^2$

Step #7:-
selection of bar
In TENSION ZONE:-
let we use #8 bars
dia $(8/8) = 1$, Area $\frac{\pi}{4}(1)^2 = 0.785 in^2$
by formula
$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{6.99}{0.785} = 8.9 \simeq 9$
so 9 #8 bars

IN COMPRESSION ZONE:-
let we use #7 bar
dia $(7/8)$, Area $\frac{\pi}{4}(\frac{7}{8})^2 = 0.601 in^2$
by formula
$\text{No of bars} = \frac{\text{Area of steel}}{\text{Area of single bar}} = \frac{4.56}{0.601} = 7.5 \simeq 8$

so 8 #7 bars.

Step#28

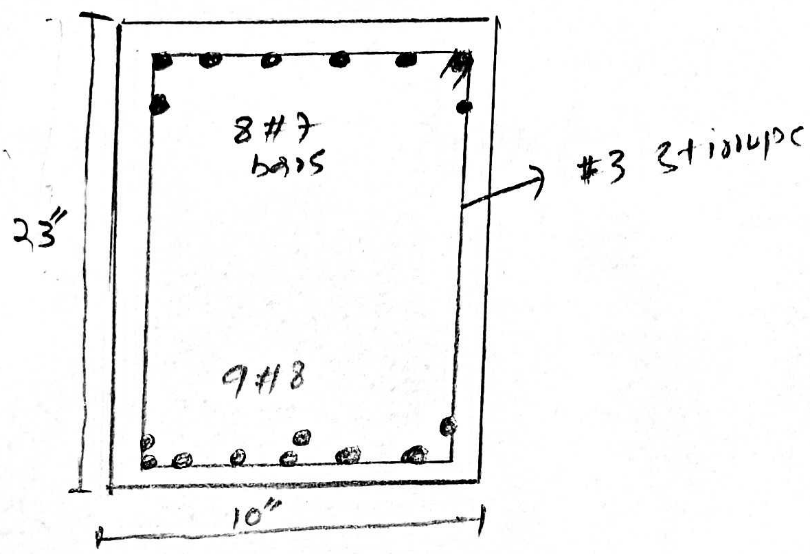
minimum width for accomodation of bars

$b_{min} = (2\times1.5) + (2\times\frac{3}{8}) + 9(8/8) + 8(8/8)$

$= 20.75''$

As $20.75'' > 10''$

So, the bars will be placed in multilayers.



Effective depth $(d) = 23 - 1.5 + \frac{3}{8} + \frac{8}{8} + \frac{1}{2}\left(\frac{8}{8}\right) = 19.6''$

Effective cover $(d') = 1.5 + \frac{3}{8} + \frac{7}{8} + \frac{1}{2}\left(\frac{7}{8}\right) = 3.18''$

Finding the design moment

$Md = \phi\left[A's \times f'y \times (d - d') + [Ast - A'st] \times fy \times \left(d - \frac{a}{2}\right)\right]$

First $a = \frac{(As - A'st)\times fy}{0.85\times f'c\times b} = \frac{(9\times0.785 - 8\times0.601)\times 6}{0.85\times3\times10} = 5.31''$

$\Rightarrow Md = 0.90\left[(8\times0.601)\times60\times(19.6 - 3.18) + (9\times0.785 - 8\times0.601)\times60 \times \left(19.6 - \frac{5.31}{2}\right)\right]$

$Md = 6328.38$

As $6328.28 > 5800$

so design is ok.

QNo# 6
Numerical

Given:-

Breadth (b) = 14"
Height (h) = 26"
concrete compression strength ($f'c$) = 4ksi
steel Tensil strength (fy) = 60 ksi
ultimate factored moment (Mu) = 6000 kips-inch
Effective depth of beam (d) = 22"
Assume effective cover (d') = 2.5"

step #1 Reinforcement ratio

by formula

$$\rho_{max} = 0.85 \times \beta \times \frac{f'c}{fy} \times \left(\frac{\varepsilon u}{\varepsilon u + \varepsilon y}\right)$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \left(\frac{0.003}{0.003 + 0.005}\right)$$

$$\boxed{\rho_{max} = 0.0180}$$

step #2 Area of steel

As we know that

$$\rho_{max} = \frac{Ast}{b \times d} \Rightarrow Ast = \rho_{max} \times (b \times d)$$

$$\Rightarrow Ast = 0.018(14 \times 22) = \boxed{5.54 in^2}$$

step #3 Design moment

~~Mu~~
by formula.

P.T.O.

$Mu_2 = \phi \times Ast \times fy \times (d - a/2)$

$\Rightarrow a = \frac{Ast \times fy}{0.85 \times f'c \times b} = \frac{5.54 \times 60}{0.85 \times 4 \times 4} = \boxed{6.98''}$

So,

$Mu_2 = 0.90 \times 5.54 \times 60 \times (22 - \frac{6.98}{2})$

$= 5537.4$ kip-inch

As, $5537.4 < 6000$

so we have to design a section as doubly reinforced.

Step #4 Difference in moment

$Mu_1 = Mu - Mu_2$

$= 6000 - 5537.4$

$\boxed{Mu_1 = 462.6 \text{ kip-inches}}$

Step #5 Area of steel

$Mu_1 = \phi \times Ast \times fy \times (d - d')$

so area of steel in compression zone will be

$A'st = \frac{Mu_1}{\phi \times \cancel{fy} \times (d - d')} = \frac{462.6}{0.90 \times 60 (22 - 2.5)}$

$\boxed{A'st = 0.44 in^2}$

Step #6 Total steel area

$As = Ast + A'st$

$= 5.54 + 0.44 = 5.98 in^2$.

Step #7:- Selection and no of bars

1) Steel in Tension zone:-

We use #7 bars

dia = (7/8)" = Area = $\frac{\pi}{4}(7/8)^2 = 0.601\ in^2$

So, No of bars = $\frac{A_{st}}{\text{Area of single bar}}$

$= \frac{5.98}{0.601} = 9.9 \approx 10$ bars.

So 10 #7 bars.

2) Steel in compression zone:-

We use #5 bars

dia = (5/8)" = Area $\frac{\pi}{4}(5/8)^2 = 0.306\ in^2$

So No of bars = A_{st}' / Area of single bar

$= \frac{0.44}{0.306} = 1.43 \approx 2$ bars

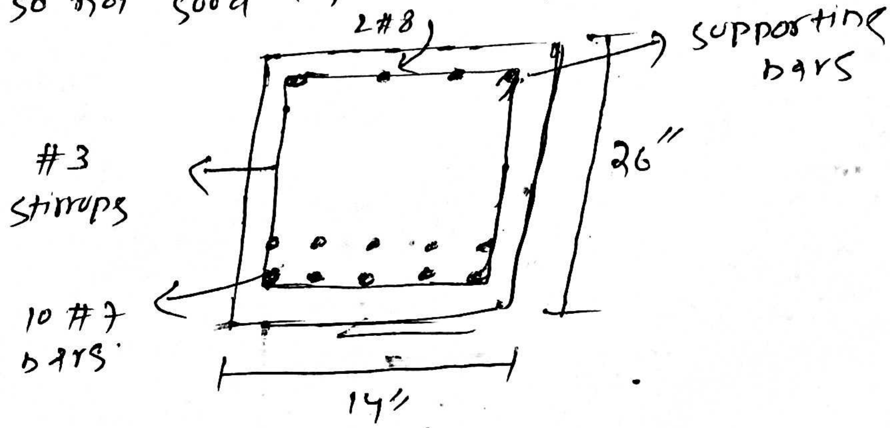
So 2 #5 bar.

Step #8 minimum width of beam

$b_{min} = 2(1.5) + 2(3/8) + 10(7/8) + 9(7/8)$

$b_{min} = 20.37\ 714"$

So not good in one layer



Effective depth (d) $= 26 - 1.5 - \frac{3}{8} - \frac{7}{8} - \frac{1}{2}(7/8) = 22.82"$

Effective cover (d') $= 1.5 + 3/8 + \frac{1}{2}(5/8) = 2.18"$

Step#9:- Design moment

$$M_d = \phi \times \left[A'_{st} \times f_y \times (d-d') + (A_{st} - A'_{st}) \times f_y \times \left(d - \frac{a}{2}\right)\right]$$

$$a = \frac{(A_{st} - A'_{st}) \times f_y}{0.85 \times f'_c \times b}$$

$$= \frac{(10 \times 0.601 - 2 \times 0.306) \times 60}{0.85 \times 4 \times 14} = 6.80''$$

$$M_d = 0.90 \left[(2 \times 0.306) \times 60 \, (22.82 - 2.18) + (10 \times 0.601 - 2 \times 0.306) \times 60 \times (22.82 - 6.80/2)\right]$$

$M_d = 7047.6$ kips - inches

As $7047.6 > 6000$

design is ok.